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(71) Applicant: KONINKLIJKE PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(72) Inventors: FLORENT, Raoul; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). BREITENSTEIN, Jacques; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(74) Agent: LOTTIN, Claudine; Internationaal Octrooibureau B.V., Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

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(54) Title: IMAGE PROCESSING METHOD AND X-RAY APPARATUS HAVING IMAGE PROCESSING MEANS FOR EXTRACTING A THREAD-LIKE STRUCTURE IN A NOISY DIGITAL IMAGE

(57) Abstract

An image processing method and an X-ray apparatus having processing means for extracting a thread-like structure represented on the background in a noisy digital original image (OI) including steps for acquiring said original image data (1) and reduction (10) said original image while using a transformation operation so as to provide a reduced image (RI), and in said reduced image: selecting (40) the most probable locations of guide-wire points by selecting (20), at each point (Pi), the direction of the guide-wire as the best match with one of several predetermined regularly oriented directions (Dk), and by probing the contrast (30) around and in said selected directions and then, in the original image: probing the contrast (50, 55) around said selected locations, and extracting the points (60, 65) which satisfy a contrast condition, connecting the points which also satisfy a connectivity criterion (70) in the reduced image (61, 66), and extracting (80) said points as guide-wire points of the original image.

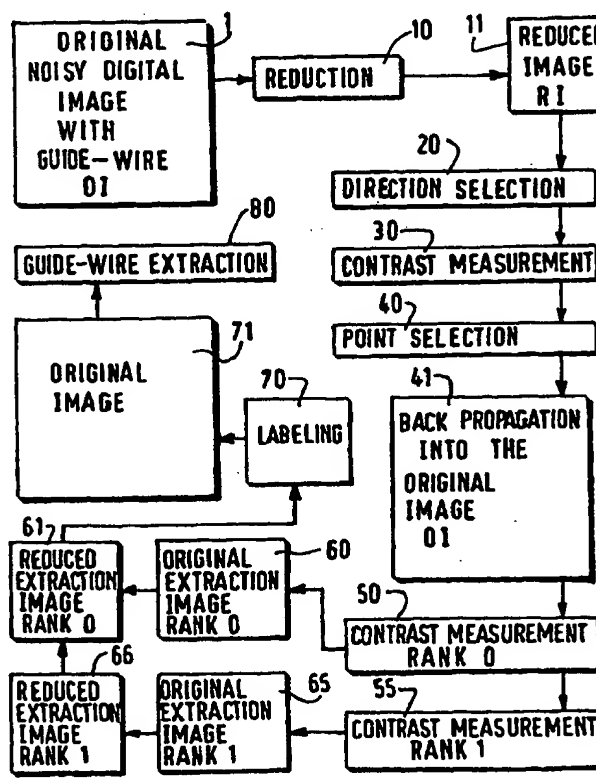

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Image processing method and X-ray apparatus having image processing means for extracting a thread-like structure in a noisy digital image.

The invention relates to an image processing method for extracting a thread-like structure represented on a background in a noisy digital image. The invention relates tin particular to an image processing method for extracting the points representing a catheter guide-wire in an X-ray fluoroscopy medical image. The invention also relates to an X-ray apparatus having means for image processing.

The invention is applied in the manufacture of X-ray apparatus.

An image processing method for extracting a catheter guide-wire is already known from US patent No. 5 289 373 5 (Zarge et alii). This document concerns a method and an apparatus for the real-time tracking of a catheter guide-wire in fluoroscopy images during interventional radiological procedures. Such a method includes three main steps :

a pixel-wise extraction step for determining whether or not each pixel should be labeled as a possible guide-wire point so as to form an image called binary peak image,

a chain model construction step followed by an identification of a guide-wire model as the most promising path among previously determined chains,

a step for the superimposition of the guide-wire model onto the live fluoroscopic images.

The first step is an iconic process that thoroughly exploits the outputs of several first and second order linear operators. The second step is non-iconic. It relates to morphological operations and to chain and tree oriented methods.

The present invention aims to provide a method which can be carried out in real time, with a substantial gain in speed with respect to the method known from the state of the art, together with a higher sensitivity and selectivity, while using processing means with a speed of the kind presently used in the state of the art.

This aim is realized by a processing method as claimed in Claim 1.

An X-ray apparatus with means for carrying out the above processing methods is disclosed in Claim 10.

The invention will be described in detail hereafter with reference to the diagrammatic figures; therein :

Fig. 1 is a functional block diagram illustrating the main steps of the method ;

Fig. 2 illustrates the image reduction step ;

Figs. 3A and 3B illustrate the direction selection step ;

Figs. 4A and 4B illustrate the reduced image contrast measurement step ;

Fig. 5 illustrates the original image contrast measurement step ;

Fig. 6A to 6E illustrate the labeling step ;

Fig. 7 illustrates an X-ray apparatus with processing means.

The invention relates to an image processing method for extracting a thread-like structure represented on a background in a noisy digital image. The invention relates in particular to an image processing method for extracting the points representing a catheter guide-wire in an X-ray fluoroscopy medical image. The invention also relates to an X-ray apparatus having means for image processing. The medical image may be an image representing blood vessels called arteriogram image. In cardiology sequences of X-ray arteriogram images are used to visualize in real time medical procedures for introducing a catheter in a vessel. Such medical procedures using a catheter rely to a great extent on the correct visibility of the guide-wire which is a metallic wire introduced in the vessel for guiding the catheter. An on-line image processing operation for extracting this guide-wire in an arteriogram image, that is the detection and location of the points belonging to said guide-wire, can serve several highly interesting purposes.

For example, an extraction mask may be constructed via the extraction operation and can be used with a noise filter in order to reduce the quantum noise of the image while maintaining the guide-wire original contrast. This contrast can be enhanced thus increasing visibility, in order to facilitate a surgical intervention by the practitioner. After complete extraction of the guide-wire, the guide-wire tip can be located and an area of interest can be defined around this tip. This enables further local processing for visibility enhancement of a so-called stent tool which is introduced into the vessel for its enlargement. In multi-plane

systems, the correct extraction of the guide-wire in several planes can offer a 3-D reconstruction of said guide-wire, offering a new visualization means to correctly guide the guide-wire within the vessel.

Fig.1 shows diagrammatically the steps of a processing method for extracting a thread-like structure represented on the background of a noisy digital image called original image. In an example described hereafter the thread-like structure is a guide-wire represented on the background of a medical fluoroscopy arteriogram. A fluoroscopy arteriogram is a digital image formed with a low X-ray level. Consequently this fluoroscopy digital image will be noisy. In the present example the process aims to extract the guide-wire in order to improve the medical image. Such an improved image may be used during a radiology-assisted surgical procedure. The following process is completely described on the basis.of its acting on one image only. So, the different steps of this process are applied to one reference image called original image. The following process also functions in real time, that is to say at a frame rate of about 25 images per second.

Referring to Fig.1, in order to reduce the computational requirements without impeding the results, and to improve the detection of the guide-wire, the input data relating to the original image, denoted is first acquired in step 1 and then reduced by an appropriate reduction transform 10. Then a preliminary extraction of the guide-wire is carried out on the resultant image which is called reduced image and denoted RI. This first extraction is performed by steps 20, 30, 40 and permits of limiting regions in which guide-wire points are to be looked for in the original image OI.

Referring to Fig.2, the reduction step 10 is carried out while using a reduction transform operation which comprises a morphological erosion operation with a flat kernel of size n x n, followed by a corresponding sub-sampling operation of 1 point every n points of the original image in two orthogonal directions such as columns and rows of the original image OI according to the axes nx and ny, respectively. The reduction transform amounts to paving the original image OI with non-overlapping contiguous blocks B of n x n points. Assuming that the original image OI has a dimension W along the nx axis and H along the ny axis, reduction by a factor n yields the corresponding dimensions W/n, H/n of the reduced image RI. In the reduced image RI the corresponding axes are called x and y. One block Bi of co-ordinates nxi, nyi of the original image OI corresponds to a point Pi of co-ordinates xi, yi in the reduced image RI. For said point Pi in the reduced image RI the intensity value Ji is determined as the intensity of one point of the block Bi in the original image OI, denoted Spi, which has the minimum intensity value Ji from among the points in said block Bi. The point

SPi of said block Bi is called the source-point and has the coordinates Sxi, Syi. The respective coordinates Sx, Sy of all source-points SP are called source-coordinates and may be stored in 1-D tables, together with the data of the reduced image RI. So this reduction transform associates with each point of the reduced image RI one counterpart point in the original image OI. Referring to Fig.1 again, the reduced image RI is stored in 11.

This morphological erosion 10 constitutes a non-linear image reduction which presents several advantages. It completely preserves the guide-wire overall shape (except its width) and produces a 1 to 1 association from the transform points to their sources in the original image. For example, practical tests have demonstrated the relevance of this morphological operation for a reduction factor n inferior to or about equal to 8, applied to an original image resolution of 512 x 512. In a fluoroscopy arteriogram the guide-wire, being a metallic tool, has a high absorption factor and does not vary in the erosion process 10. Said guide-wire is substantially preserved after erosion and sub-sampling. Another beneficial aspect of the non-linear image reduction 10 is its ability to make the guide-wire, being an elongate mono-dimensional structure, thinner in the reduced image than in the original image, this in turn makes its extraction easier. It is a reason why this first step 10 enhances the detection of the guide-wire.

Referring to Fig.1, each point considered in the reduced image RI, represented in block 11, is A PRIORI considered as a potential guide-wire point. The process also includes a direction selection step 20 for determining a most probable guide-wire direction at that point. Referring to Fig.3A, for that purpose a predetermined number of regularly oriented directions denoted Dk, is chosen for the whole image. The step 20 includes a tangential direction selection operation which associates one of the predetermined directions Dk with each point as the best match according to a given selection criterion. The Dk directions are measured by angles θk with respect to a reference axis, where k is the number of Dk directions. The reference axis may be the axis X parallel to x.

A selection criterion is designed and applied to each point. Said criterion expresses the fact that a point Pi is a guide-wire point whenever said point is crossed by a dark fine segment whose angle with respect to the different Dk directions is considered. There may be several Dk candidates. One Dk direction is selected from among the candidates when the average gray-level in both orientations of said Dk direction is minimum, that is to say along the orientation θk, corresponding to the first orientation of said Dk direction, and along the second orientation $\theta k+\pi$. The corresponding orientation axis Dk of angles θk, $\theta k+\pi$ crosses the candidate guide-wire point Pi. Referring to Fig.3A, 8 directions, such as k = 8, have been

chosen. This number proved to be a good compromise providing both a good resolution and a good calculation efficiency. This choice of the number k, however, is not restrictive.

Referring to Fig.3B, in order to carry out step 20 for direction selection, local averages are calculated through the use of 1-D filters Fk having oriented kernels in these directions Dk so as to select the minimum gray-level as required.

For this purpose, the reduced image RI is scanned by way of a standard procedure which is known to those skilled in the art, for example parallel to the X axis, point after point, from the upper left corner of the reduced image RI to the lower right corner. At each current point Pi, a first direction Dk is processed. In said first direction Dk a first gray-level average is formed over a few points, for instance 3 to 6 points, in the orientation θk. Then, a second gray-level average is formed over the same number of points in the orientation $\theta k+\pi$. Then, the maximum gray-level value of the first and second gray-level averages is determined and retained in relation to said first processed direction Dk. All the other directions of the k directions Dk are processed in the same way so as to determine a set of a number k of maximum gray-level values which are retained in relation to each of said directions Dk.

Then, a minimum gray-level value is determined and retained from among said set of k maximum gray-level values. Said minimum gray-level value is related to a corresponding Dk direction having an orientation θk or $\theta k+\pi$ which is then selected as the most probable direction Dk of a guide-wire crossing said current point Pi in the reduced image RI. The reduced image RI is scanned point after point by way of the standard scanning procedure and one selected direction is retained for each current point.

Referring to Fig.1, once a direction has been estimated at each current point of the reduced image RI, a step 30 for local contrast measurement is performed in said reduced image. For this purpose, the reduced image RI is scanned again by way of the standard scanning procedure. Referring to Figs.4A, 4B, at each current point Pi associated with its selected direction Dk there is calculated, a difference of gray-levels, measuring the contrast between the potential guide-wire segment and its neighborhood. This calculation is performed by evaluating the difference between a first term, integrating the local gray-levels around the selected direction Dk, that is to say in the orthogonal directions of orientations $\theta k-\pi/2$ and $\theta k+\pi/2$, and a second term which estimates the gray-levels of points in the selected direction Dk of orientation θk and $\theta k+\pi$. The first term is called orthogonal measurement and the second term is called tangential measurement. When evaluated at an actual guide-wire point, the orthogonal measurement is greater than the tangential measurement.

The tangential measurement at θk and θk+π may be the average value or preferably the median value, denoted R, of the gray-levels of points belonging to a short segment, denoted TPk, of a predetermined number of points oriented in the selected direction Dk. The current point Pi is disposed at the center of the segment TPk. The orthogonal measurement uses a set of local gray-level averages around the selected Dk direction, that is to say to either side of the assumed guide-wire points TPk. This measurement excludes the central points meaning the points of the segment TPk. This defines two dead zones DZ1, DZ2 and two neighborhoods OP1, OP2, respectively, to each side of the segment TPk. Each neighborhood is divided into lines of points. In an example the segment TPk has 3 points and the first and second neighborhoods are divided into 3 lines, each L11, L12, L13 and L21, L22, L23, respectively, which are orthogonal to the segment TPk. The lines are aligned on the respective points of the segment TPk. The local gray-level averages of the orthogonal measurement may be determined according to one of the following feasible sub-steps.

A first possible sub-step consists in evaluating one average of the gray-level values on each line L11, L12, L13 of the first neighborhood OP1 and on each line L21, L22, L23 of the second neighborhood OP2, thus determining a first set of 3 averages and a second set of 3 averages, i.e. 6 averages. This substep subsequently consists in evaluating a first minimum gray-level value from the first set of averages and a second minimum gray-level value from the second set of averages, followed by an evaluation of the minimum gray-level value denoted R6, from said first and second minimum gray-level values, i.e. taking the minimum gray-level value of said averages.

A second possible sub-step consists in evaluating a first, a second and a third gray-level average, respectively, on all points of the first lines L11, L21, on all points of the second lines L12, L22, and on all points of the third lines L13, L23 of the two neighborhoods OP1, OP2, followed by the evaluation of the minimum gray-level value, denoted R3, of these first, second and third averages. In this contrast measurement step 30, the use of R3, resulting from a more permissive calculation than R6, is preferred in particularly noisy conditions. The contrast measurement 30 is provided either by the difference R1 or R0 : $R0 = R6 - R$

$$R1 = R3 - R$$

Referring to Fig.1, after the contrast measurement 30 a point selection operation 40 is performed in the reduced image RI. For that purpose, the contrast measurement 30 is directly used to select guide-wire point candidates in the reduced image RI in the step 40. This may be achieved through the use of a threshold. In order to perform the threshold operation, the points of the reduced image where a positive contrast has been found may be selected. A

threshold value that is automatically tuned to select a predetermined number of point candidates may also be used. It is advantageous that in the reduced image RI the local averages are calculated while using 1-D filters which perform direct computations of cumulated gray-level summations on whole straight digital lines oriented according to the different Dk directions and covering said whole reduced image RI. In order to perform such 1-D filtering, the whole reduced image RI is submitted to a preliminary regular scanning procedure which is different from a standard procedure as known to those skilled in the art in that said preliminary procedure is performed in all predetermined directions Dk instead of, for example, along only one axis X. On each straight scanning line the cumulated summations of gray-levels are calculated from a first point at one extremity of the scanned line to a last point at the other extremity of said scanned line. These cumulated sums are calculated only once and are used for the evaluation of all averages which are necessary in the steps 20 for direction selection and the step 30 for contrast measurement in the reduced image RI. Once the cumulated summations are stored, the reduced image RI is scanned according to the standard procedure known to those skilled in the art, for example parallel to the X axis, and for each current point of the reduced image RI, the local average at a given number of points, in a direction Dk, is then obtained by forming an appropriate difference from cumulated sums calculated in said direction.

Since the morphology-based transform 10 producing the reduced image also defines a 1-to-1 mapping from the pixels of said reduced image to their sources in the original image, the selection process 40 in the reduced image RI also straight forwardly induces a selection process in the original image OI. So the same directions are used in the original image as in the reduced image. In step 41 the selected points in the reduced image are thus propagated to the original image OI together with their selected orientations. These selected points and the neighborhoods defined around said points in the original image may be used to validate or invalidate the first selected candidates in the reduced image RI. Tests have proved that the direction selection applied in the reduced image was appropriately reliable.

Referring to FIG.1, the process also includes at least one step 50 for contrast measurement in the original image OI. This step 50 is carried out in the original image OI in a way similar to the step 30 for contrast measurement in the reduced image RI. As opposed to the difference with the step 30 performed in the reduced image RI, the 1-D filters used to calculate averages in the original image OI do not use cumulated sums. Instead they perform calculations on discrete points. Large numbers of calculations are no longer required for the original image OI since the points of interest have already been selected in the reduced image

RI and propagated to the original image OI. The original image OI is scanned while using a standard procedure known to those skilled in the art, for instance point after point on digital straight lines parallel to the nx axis which is parallel to the X axis, from the upper left corner to the lower right corner of said original image. Contrast measurements are performed each time a source-point SPi corresponding to a selected point Pi of the reduced image is encountered.

Referring to Fig.5, a difference of gray-level values, measuring the contrast between the potential guide-wire segment and its neighborhoods, is calculated. This calculation is performed by evaluating again a difference between a first term of orthogonal measurement and a second term of tangential measurement. However, a major difference consists in that this contrast measurement in the original image OI is less permissive than the step 30 in the reduced image RI. The selection in the reduced image RI is especially intended to reduce the computation load, whereas the contrast measurement in the original OI image is responsible for the selection of actual candidates.

The tangential term may be defined as the average or the median of the values of the pixels that lie on a correctly oriented short segment. The orthogonal measurements use the same set of 1-D kernels as in the step 30 for the reduced image RI. These kernels are orthogonal oriented segments with dead zones excluding the guide-wire area. An aggressive criterion is designed as an average of rank filter outputs. The chosen rank value defines an ordered family of contrast measurements. This property will bring advantages in the further step for the extraction process. In order to calculate the orthogonal measurement in the original image OI the potential guide-wire segment is denoted STPk, corresponding to the segment TPK in the reduced image RI, and the two neighborhoods are denoted SOP1, SOP2 and correspond to the two neighborhoods OP1, OP2 in said reduced image RI. Dead zones SDZ1, SDZ2 are also defined. The numbers of points of the segment STPk and the neighborhoods SOP1, SOP2 are determined as a function of the aggressiveness desired for a further described criterion and as a function of the noise level in the image. In an example the two neighborhoods SOP1, SOP2 are divided into lines SL11,....SL17 and SL21,...SL27 which are orthogonal to the segment STPk and said lines are aligned on the respective points of the segment STPk which is itself aligned on the direction Dk propagated from the reduced image RI.

Preferably, the contrast measurement is effected with two ranks : in a first contrast measurement step 50 for a first rank, denoted rank 0, and in a second contrast measurement step 55 for a second rank, denoted rank 1, which is more permissive than the

rank 0. For the evaluation of the contrast measurement in the step 50 with the first, less permissive rank, called rank 0, the method includes sub-steps for : evaluating the tangential term, denoted Q, as the gray-level average value on the segment STPk positioned along Dk ; evaluating the orthogonal term, including the selection of one minimum gray-level value per line, that is to say the minimum gray-level value on each line, line after line SL11, ..SL17 of the first neighborhood SOP1, selecting the minimum gray-level value on each line, line after line SL21,...SL27 of the second neighborhood SOP2, and then forming the average of all selected minimum gray-level values in the two neighborhoods, yielding a first orthogonal term of gray-level value denoted Q6.The contrast measurement with the first rank 0 is thus given by the following difference :

$$Q0 = Q6 - Q$$

For evaluating the contrast measurement in the second step 55 with the second, more permissive rank, called rank 1, the process includes sub-steps for: evaluating the tangential term denoted Q, as the gray-level average value on said segment STPk positioned along Dk ; evaluating the orthogonal term, including the selection, on each line and in each neighborhood, of the gray-level value which is just above the minimum gray-level value determined for the processing with the rank 0, called above minimum gray-level value ; forming subsequently the average of all selected above minimum gray-level values in the two neighborhoods, yielding a second orthogonal term of gray-level value denoted Q3. The contrast measurement with the second rank 1 is then given by the following difference :

$$Q1 = Q3 - Q$$

Referring to FIG.1, a step 60 for the extraction in the original image OI is also performed. A predetermined threshold is used to select the points of the original image where the contrast measurement resulting from the step 50 has a predetermined level which is considered sufficient. This predetermined threshold value can be adapted to a number of points which is chosen to be taken into account. Since two contrast measurements have been performed in the original image during the steps 50, 55, two original extraction images can be created by carrying out a further step 65 which is similar to the step 60. Thus, a first original extraction image, denoted OI0 and corresponding to the very strict contrast measurement Q0 with rank 0, and a second original extraction image denoted OI1 and corresponding to the more permissive contrast measurement Q1 with rank 1, are created in the steps 60 and 65, respectively. Once created the points of these two original extraction images OI0, OI1, are back-propagated into the reduced image and stored; this takes place in a step 61 and a step 66, respectively, thus creating two reduced extraction images denoted RI0, RI1, respectively.

Once selected in the steps 60 or 65, points in the respective original images OI0, OI1 produce, by way of the steps 61 or 66, extraction counterparts in the corresponding reduced images RI0, RI1.

Referring to FIG.1, a further step 70 for labeling is carried out. Two procedures are proposed for this labeling step 70. The first procedure is carried out in only one reduced image, for instance the reduced extraction image of rank 0 which is called RI0. The second procedure is carried out in the two reduced images constituted by the two reduced extraction images denoted RI0 and RI1 respectively.

Referring to Figs. 6A to 6C, the first procedure for labeling may comprise two passes.

Referring to Fig.6A, the first pass comprises at least one condition which is the definition of a first labeling distance threshold denoted L, for instance 1 or 2 points : For example the points P1, P2 may be coupled. Referring to Fig.6B, this condition may be combined into two criterions : a first criterion for labeling which includes the condition that point couples are connected only when the corresponding directions Dk associated with each point are close together, such as P3, P4 , and a second criterion for labeling which is illustrated by Fig.6C and may be combined with the first criterion and consists in choosing elongated ellipses to define the distance for connecting couples, said ellipses being oriented according to the angle θ k of the local guide-wire direction Dk. In this first pass different sets of points are connected when they satisfy the predetermined conditions and criterions. They form respective regions of connected points called connected components and denoted LB, which each receive a label such as LB1, LB2, LB4, LB5. This first pass may also include sub-steps for component suppression when the number of points inside a labeled component is less than a predetermined number, for example LB3 which has only one point. Other sub-steps for component suppression may be performed when a predetermined contrast level is not reached within some components.

The second pass includes a determination of the end points in the components, such as P6, P7 in Fig.6C, and of a second labeling distance threshold for connecting end points subject to the aforementioned first and second criterions. For this purpose the second labeling distance threshold is more permissive than the first one. When end points are connected, the corresponding connected components are merged.

The second proposed labeling procedure is a hysteresis-based labeling operation which is carried out in the two reduced extraction images RI0, RI1 in order to perform an efficient connectivity analysis. Referring to Figs.6D and 6E, in said reduced extraction images

RI0, RI1 the respective extracted points propagated from the two original extraction images provided by the step 60 are analyzed with respect to their connectivity. Each of said first and second reduced extraction images RI0, RI1, of rank 0 and 1, respectively, is first decomposed into connected components as described above in relation to one reduced extraction image RI0. Then a hysteresis-based operation is performed according to which : in the second reduced extraction image RI1 (rank 1) only those components (such as LB1) that share points with at least one component of the first reduced extraction image RI0 (rank 0) are selected. This operation ensures both high selectivity and sensitivity ; there is defined a subset of the connected components which contains the connected components which were obtained by a permissive contrast measurement and which at the same time lie over a connected component obtained with a restrictive measurement.

The points that belong to the retained connected components are eventually propagated into the original image OI (in the step 71) as finally extracted points.

Referring to Fig.1, a final guide-wire extraction and extrapolation is carried out in the original image in a step 80. For this purpose, around the extracted points there may be added neighboring points that belong to a centered correctly-oriented segment resulting, for example, from extrapolations. Fine line segment or oriented ellipses may be used for that purpose. This operation improves the guide-wire coverage. During the extrapolation process it may be checked that the extrapolated points indeed belong to the guide-wire : at their locations the gray-level values in the original image must be substantially the same as the gray-level values of the source-points. The magnitude of the discrepancy is estimated in comparison with the estimated noise standard deviation.

An advantageous application of the described process with the steps 10 to 80 lies in the noise reduction field.

A medical X-ray apparatus as represented in Fig.7 may include means for acquiring digital medical image data called original images OI, and digital processing means for processing these data so as to extract thread-like objects such as guide-wires and catheters according to the processing method described above. The X-ray apparatus includes an X-ray source 101, a table 102 for receiving the patient, and an optical system 103, 104 for providing image data to the processing means 105. The processing means may be a processor having digital calculation means for processing the data and are storing means, such as memories, for storing the data. The processing means may also have at least one output 106 coupled to display means including a screen 107 for displaying the medical original images and the

processed medical images, in such a way that the displayed processed images may be of assistance to the practitioner during a medical intervention.

CLAIMS:

1. An image processing method for extracting a thread-like structure represented on the background in a noisy digital image, called original image (OI), including steps for acquiring said original image data (1) and reduction (10) said original image while using a transformation operation so as to provide an image called reduced image (RI), and in said reduced image:

selecting (40) the most probable locations of guide-wire points by selecting (20), at each point (Pi), the direction of the guide-wire as the best match with one of several predetermined regularly oriented directions (Dk), and by probing the contrast (30) around and along in said selected directions and then, in the original image:

probing the contrast (50, 55) around the selected locations previously determined in the reduced image, and extracting the point (60, 65) which satisfy a contrast condition in the original image,

connecting the points which also satisfy a connectivity criterion (70) in the reduced image (61, 66),

and extracting (80) said points as guide-wire points of the original image.

2. An image processing method as claimed in Claim 1, wherein the reduction transform operation (10) includes a morphological erosion with a flat kernel, followed by a corresponding sub-sampling operation.

3. An image processing method as claimed in one of the Claims 1 or 2, wherein the selection (20) of the most probable direction of the guide-wire at each point of the reduced image (RI) includes the definition of a predetermined number (k) of regularly oriented directions (Dk), and a tangential direction selection according to a criterion which selects a point as a possible guide-wire point whenever the average gray level value on an oriented kernel in one of the directions (Dk) crossing the point is minimum with respect to the other directions.

4. An image processing method as claimed in Claim 3, wherein the contrast measurement (30) is performed at each point of the reduced image (RI) by evaluating a difference (R0, R1) between a local average (R) in the tangential direction along the selected directions (Dk) and local averages (R6, R3) in the orthogonal direction with respect to the selected direction (Dk).

5. An image processing method as claimed in Claim 4, wherein the point selection (40) in the reduced image is performed by selecting a predetermined number of candidate points satisfying a criterion of maximum of contrast measurement in the selected direction (Dk).

6. An image processing method as claimed in Claim 5, wherein the selected points are back-propagated into the original image (41), together with their selected orientations, and further contrast measurements (50, 55) are performed in said original image by evaluating a difference (Q0, Q1) between a local average (Q) in the tangential direction (Dk) and local averages (Q6, Q3) in the orthogonal direction with respect to the selected direction (Dk).

7. An image processing method as claimed in Claim 6, wherein the local average in the orthogonal direction is performed with a first ranking taking into account a number of points in neighborhoods in said orthogonal directions which have minimum gray-level values, and wherein the local average in the orthogonal direction is further performed with a second rank with more permissive conditions, taking into account points in said neighborhoods in said orthogonal direction which have gray-level values just above the minimum gray-level values evaluated for the first rank.

8. An image processing method as claimed in Claim 6 or 7, wherein the point extraction (60,65) in the original image is performed by selecting the points of the original image which satisfy a criterion of maximum contrast measurement either with rank 0 and rank 1 or with rank 0, and wherein the selected points are back-propagated into the reduced image, thus creating a first reduced extracting image of rank 0, and occasionally a second reduced extracting image of rank 1.

9. An image processing method as claimed in Claim 8, wherein the points of each reduced extracting image (61, 66) are submitted to a connectivity criterion (70) for forming

connected components which each receive a label, wherein either the labeled components are selected in the reduced extraction image of rank 0 or the labeled components are selected from among those components of the first and the second reduced extracting image which lay one upon the other, and wherein the selected labeled components are back-propagated (71) into the original image and ultimately extracted (80).

10. An X-ray apparatus having means for acquiring medical digital image data and digital processing means having access to said medical digital image data in order to carry out a processing method as claimed in one of Claims 1 to 9, and having display means, including a screen, for displaying the medical digital images and the processed medical digital images.

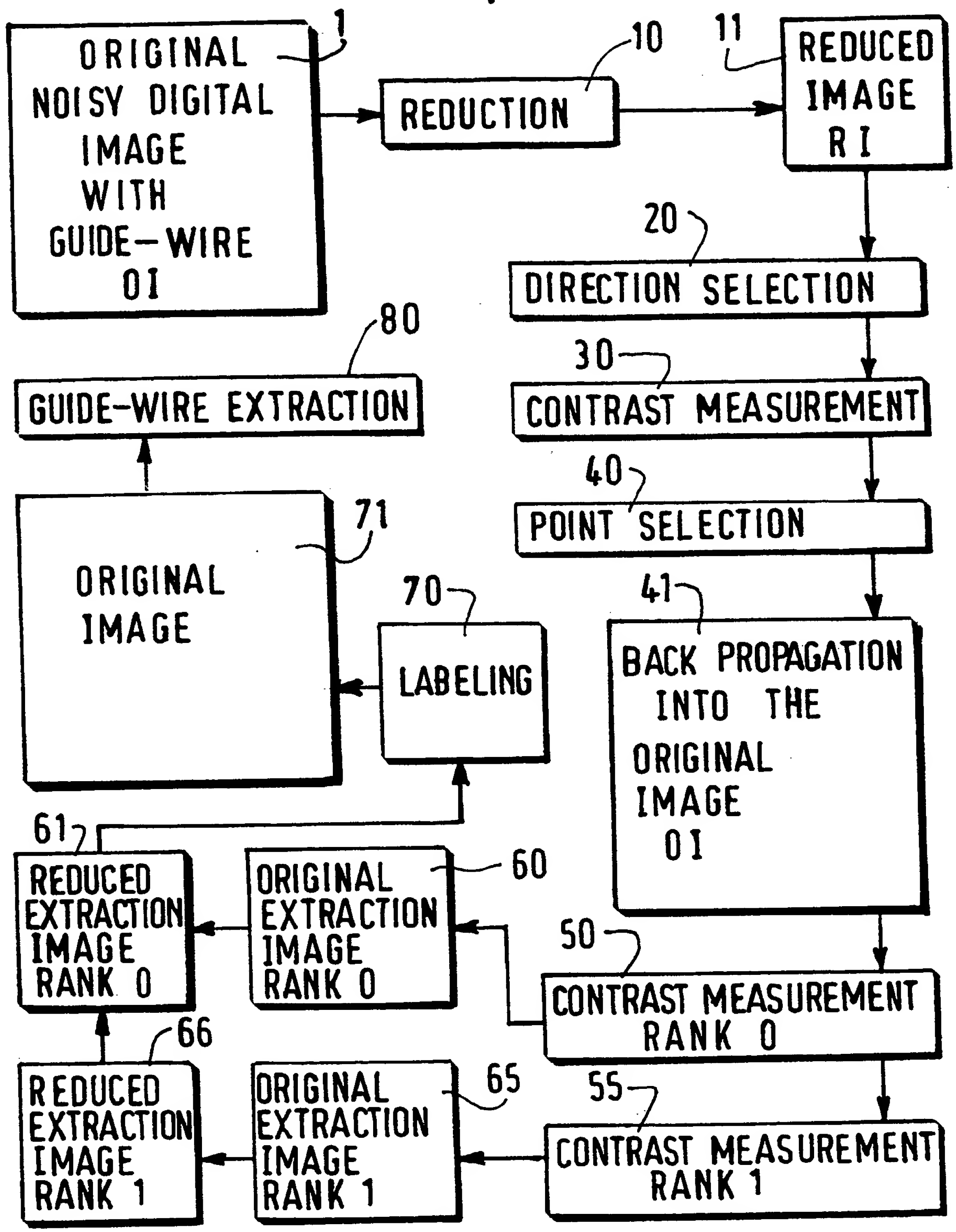
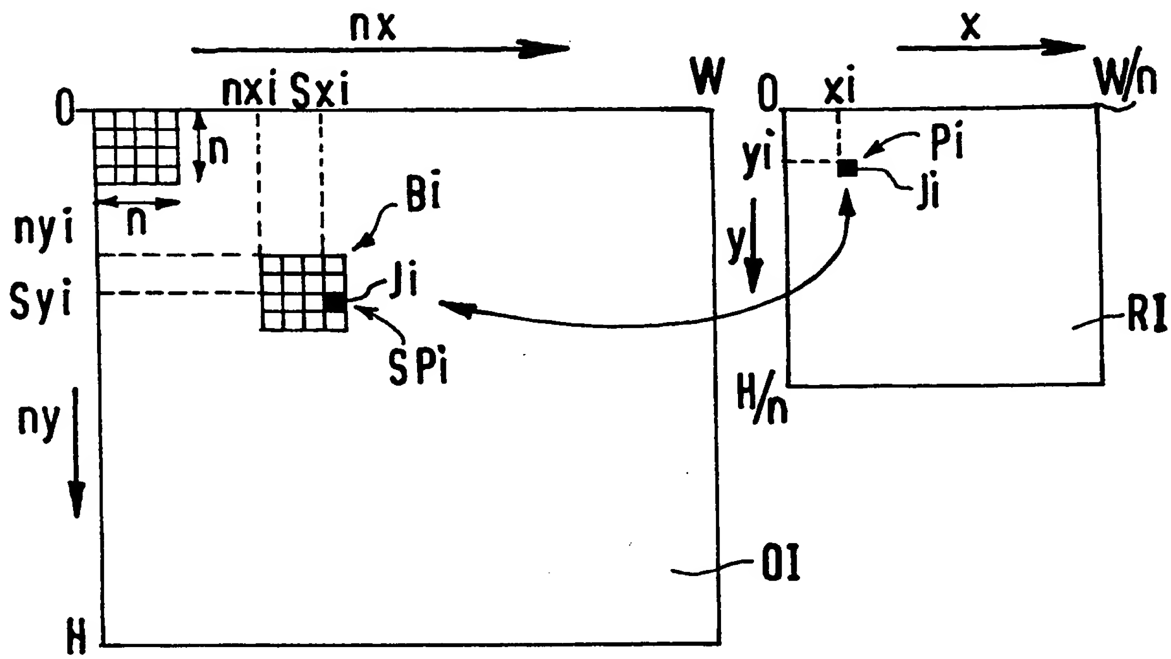

ORIGINAL NOISY DIGITAL IMAGE WITH GUIDE-WIRE OI
1
REDUCTION
10
11
REDUCED IMAGE RI
20
DIRECTION SELECTION
30
CONTRAST MEASUREMENT
40
POINT SELECTION
41
BACK PROPAGATION INTO THE ORIGINAL IMAGE OI
80
GUIDE-WIRE EXTRACTION
71
ORIGINAL IMAGE
70
LABELING
61
REDUCED EXTRACTION IMAGE RANK 0
ORIGINAL EXTRACTION IMAGE RANK 0
60
50
CONTRAST MEASUREMENT RANK 0
66
REDUCED EXTRACTION IMAGE RANK 1
ORIGINAL EXTRACTION IMAGE RANK 1
65
55
CONTRAST MEASUREMENT RANK 1

FIG.1


nx
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W
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nxi Sxi
xi
W/n
n
yi
Pi
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Bi
nyi
y
Syi
Ji
SPi
RI
H/n
ny
OI
H

FIG. 2

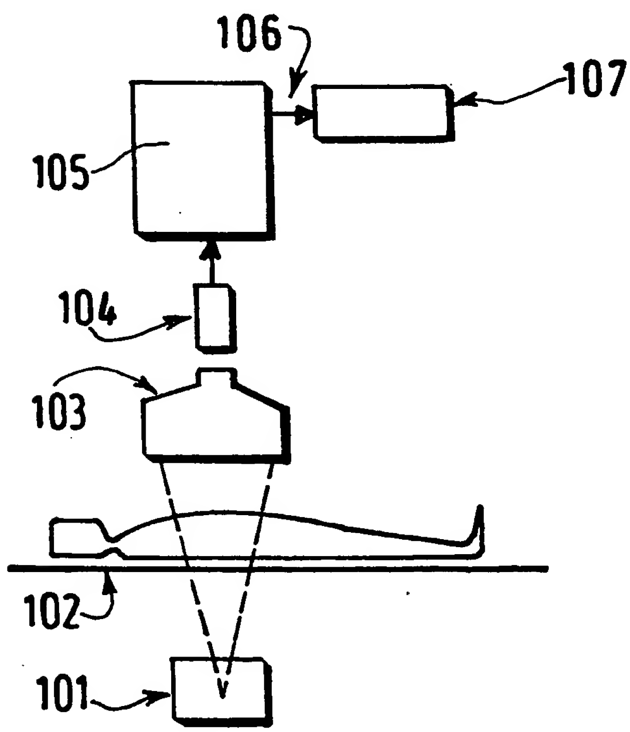
106
107
105
104
103
102
101

FIG.7

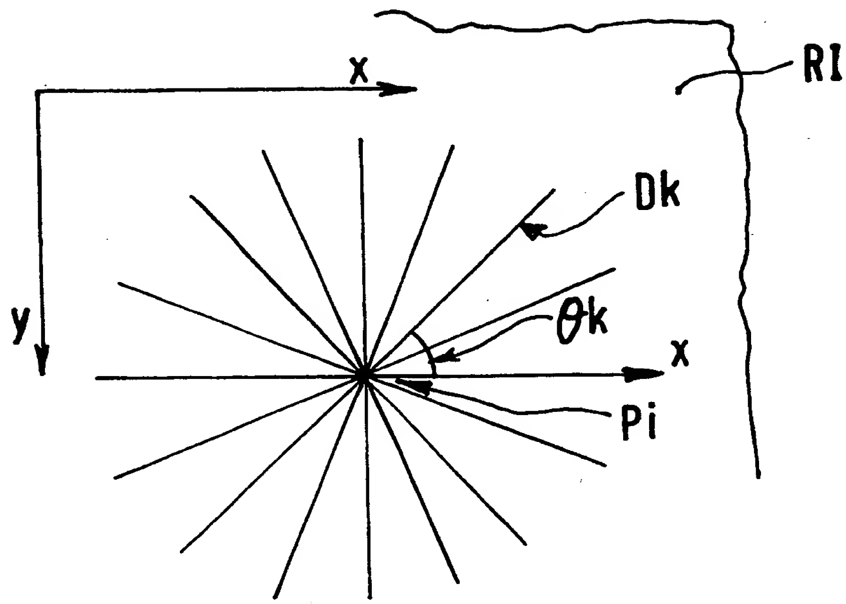

FIG.3A

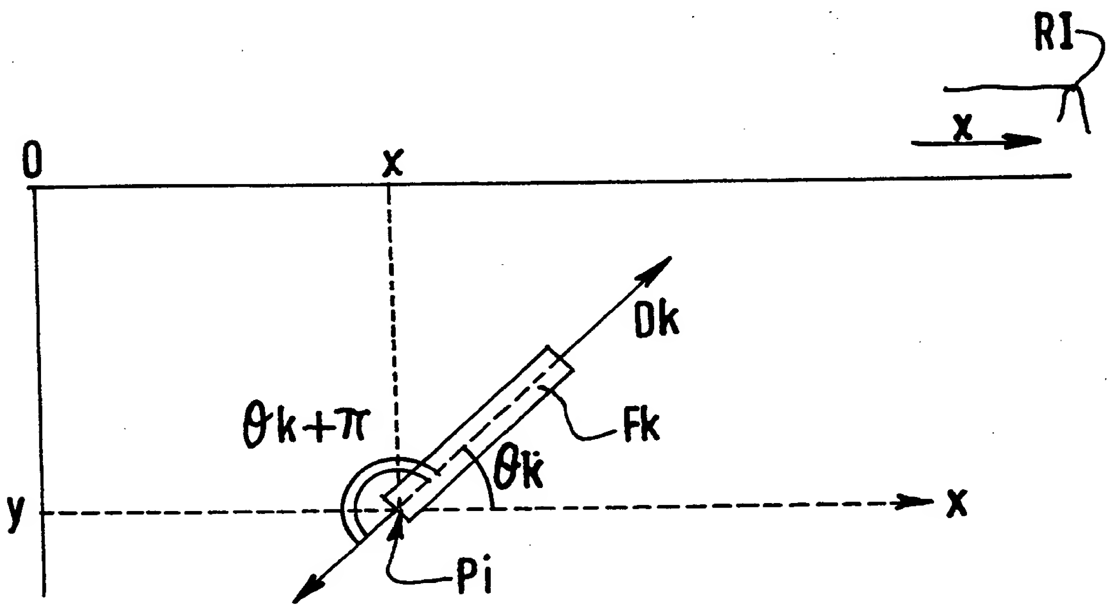

FIG.3B

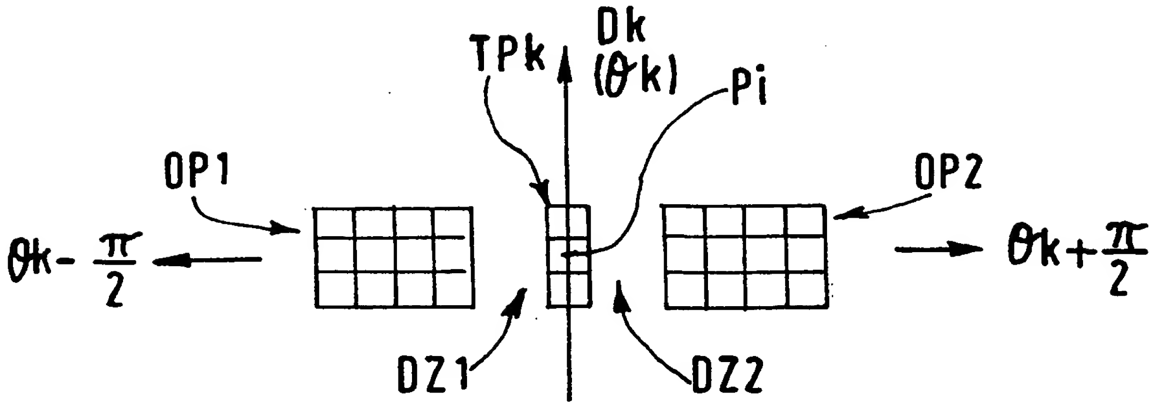

FIG.4 A

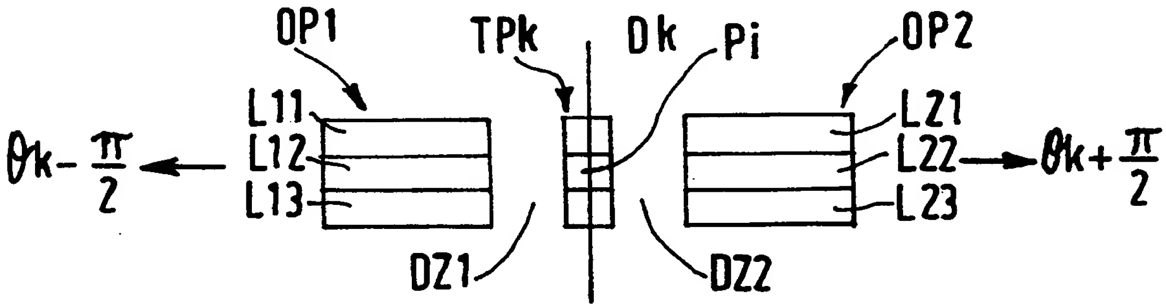

FIG.4 B

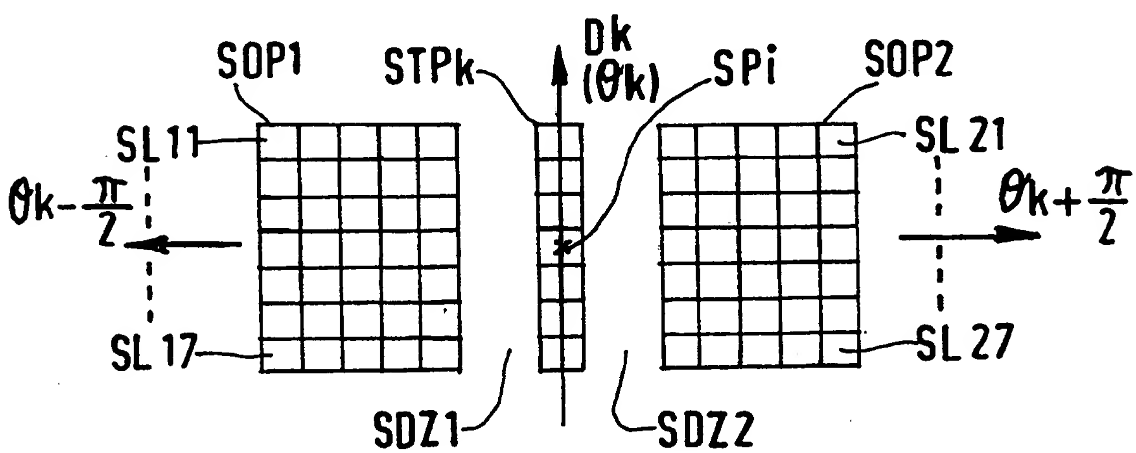

FIG.5

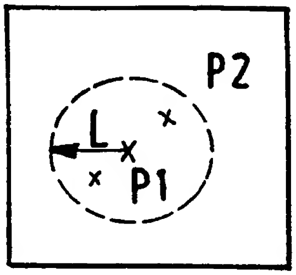

FIG.6A

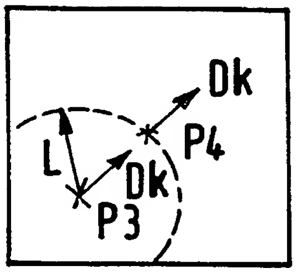

FIG.6B

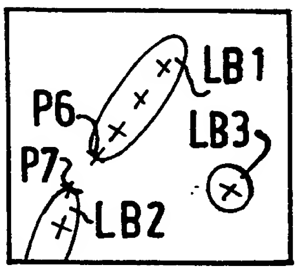

FIG.6C

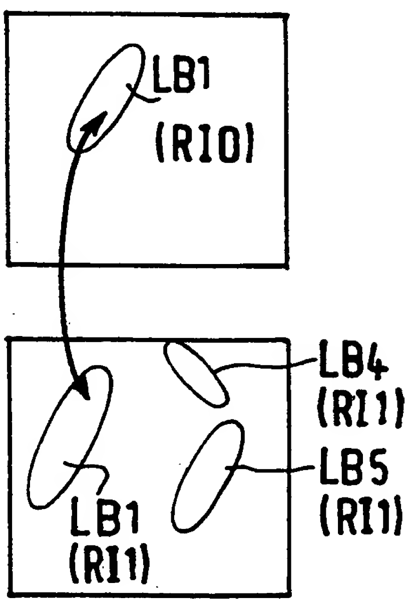

FIG.6D

FIG.6E

INTERNATIONAL SEARCH REPORT

Inte ional Application No
PCT/EP 99/10216

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06T5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 94 19759 A (SIEMENS AG ;KUTKA ROBERT (DE); STIER SEBASTIAN (DE)) 1 September 1994 (1994-09-01) abstract page 1, line 26 - line 34 page 3, line 20 -page 4, line 34	1-10
A	US 5 274 551 A (CORBY JR NELSON R) 28 December 1993 (1993-12-28) abstract column 5, line 28 -column 6, line 2; figures 5-8 column 6, line 20 - line 31	1-10

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 April 2000	02/05/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Gonzalez Ordonez, O

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	PALTI-WASSERMAN D ET AL: "IDENTIFYING AND TRACKING A GUIDE WIRE IN THE CORONARY ARTERIES DURING ANGIOPLASTY FORM X-RAY IMAGES" IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING,US,IEEE INC. NEW YORK, vol. 44, no. 2, 1 February 1997 (1997-02-01), pages 152-164, XP000658738 ISSN: 0018-9294 abstract page 155, left-hand column, line 47 -page 156, right-hand column, line 22 page 158, left-hand column, line 35 - line 52	1-10
A	AUFRICHTIG R ET AL: "MARKING ARTERIES AND CATHETERS IN X-RAY FLUOROSCOPY USING MORPHOLOGICAL FILTERING" PROCEEDINGS OF THE ANNUAL INTERNATIONAL CONFERENCE OF THE ENGINEERING IN MEDICINE AND BIOLOGY SOCIETY,US,NEW YORK, IEEE, vol. CONF. 14, 1992, pages 1854-1855, XP000514459 ISBN: 0-7803-0786-0 abstract paragraph 'THEORY!; figure 1	1-10

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte. .onal Application No
PCT/EP 99/10216

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9419759 A	01-09-1994	DE 4304860 A	18-08-1994
		DE 59401541 D	20-02-1997
		EP 0685089 A	06-12-1995
		JP 8506677 T	16-07-1996
US 5274551 A	28-12-1993	NONE	